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Innovative Clean Coal Technology Program

INTERIM TECHNICAL REPORT

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EXECUTIVE SUMMARY

The Passamaquoddy Technology Recovery Scrubber™ has been built and is being demonstrated on-line at the Dragon Products Plant in Thomaston, Maine. This Innovative Clean Coal Technology is using waste cement kiln dust (CKD) to scrub sulfur dioxide, some NOx, as well as a small amount of carbon dioxide from a coal burning kiln exhaust flue gas. The former two pollutants contribute greatly to acid precipitation while the latter pollutant contributes to the greenhouse effect. The process also enables the cement plant to reuse the treated CKD, eliminating the need to landfill this material. Potassium, the offending contaminant in the CKD, is extracted in a useful form, potassium sulfate, which is used as a fertilizer. These useful products generate income from operation of this Recovery Scrubber.

The Participant in this project along with the United States Department of Energy is Passamaquoddy Technology, L.P. The host facility is Dragon Products, Inc., which operates a wet process cement kiln in Thomaston, Maine. Design contractors were HPD Inc. of Naperville, Ill., and A.B.B. Environmental of Portland, Maine. Cianbro, Inc. of Pittsfield, Maine was employed to construct based on these designs.

System start-up was begun in late December of 1990. At that time, several mechanical problems were encountered. These included: axial flow pump seal failures; failure of the forced draft fan bearings; and corrosion of the shell of the Crystallizer Heat Exchanger. These and other relatively minor problems were resolved enabling Phase III to begin on August 20, 1991.

While inefficiencies are still being worked out, major program objectives are being met. In particular, sulfur dioxide emissions are typically 10% or less of the kiln exhaust levels. Treated kiln dust has been returned to the cement plant and used to make cement. Potassium sulfate fertilizer has been crystallized; however, because of its present high moisture level, we have not made pellets from the centrifuge cake. Resolution of remaining operability problems is well in hand and should not hamper attainment of all project goals.

Independent stack testing to determine the accuracy of monitoring instruments has been performed. However, instrument error has delayed issuance of the final test results. Preliminary results do, however, indicate excellent sulfur dioxide scrubbing and particulate removal.

INTRODUCTION

PROJECT FORMATION

The Passamaquoddy Technology Recovery Scrubber™ was invented by Dr. Garrett Morrison. This followed his development work on a less sophisticated system also formerly installed at the Dragon Products Plant. Dr. Morrison was at that time employed by Dragon Products, Inc., which was then owned by the Passamaquoddy Tribe of eastern Maine. He was assigned to perform research and development, especially toward the solution of environmental problems at the plant.

Soon after being employed by Dragon Products, Dr. Morrison became involved in the search for a low cost scrubbing system for sulfur dioxide emissions from the cement kiln. The importance of this project resided in the need for the plant to keep its costs down by burning low cost high sulfur coal. Dr. Morrison's solution was to collect leachate from the plant's CKD landfill and to spray this alkaline liquid between the kiln exhaust and the dust collection system. In this way, the alkaline droplets reacted with acidic gas components forming neutral salts. However, the water in the droplets quickly evaporated, leaving only particles of the salts to be collected dry by the dust collection system. This system was successful in allowing the plant to meet its state and federal limits while remaining economically competitive.

While this scrubber provided a low cost solution to the flue gas sulfur dioxide suppression problem, potential refinements lay ahead.

For many years, researchers have sought to clean up waste CKD in such a way as to allow recycling of the recovered dust back to the cement kiln. The contaminants that they sought to remove were typically the alkalis (e.g. potassium) and chlorides or sulfates. However, the pozzolonic and scaling properties of CKD and the problems of disposal of soluble components confounded attempts at economic recycling of CKD. Even the landfilled and naturally leached dust at Dragon Products retained sufficient alkali to render it unusable as cement kiln feed.

Dr. Morrison could see that it would be necessary to destroy the pozzolonic and scaling properties to make a CKD recovery system workable. However, large quantities of expensive chemicals could wreck the economics of such a process.

The solution to these problems was the common greenhouse gas, carbon dioxide. This gas is plentiful when carbon containing fuels such as coal are burned. Carbon dioxide forms carbonic acid in aqueous solution, which has the effect of neutralizing basic ingredients in the CKD. The overall result is the destruction of the pozzolonic or adhesive characteristics of the dust. Additionally, by maintaining a high CO_2 level in solution for a sufficient length of time, one can also greatly affect the scaling properties of CKD.

The main scaling ingredients formed by CKD in contact with gasses containing oxides of sulfur are calcium sulfate and calcium sulfite. The latter can oxidize to the sulfate. However, calcium sulfate is two orders of magnitude more soluble than calcium carbonate. Hence, in a well carbonated solution, calcium sulfate can be driven below its solubility limit; in fact, particles of calcium sulfate can be converted to calcium carbonate, releasing sulfate for reaction with other species that will not cause scaling problems.

Dr. Morrison therefore proposed to intimately blend a slurry of CKD with cement kiln exhaust flue gases. The flue gas is not only contaminated by oxides of sulfur, but is naturally very high in CO_2 . The mixing action would therefore saturate the slurry solution in carbon dioxide while capturing the oxides of sulfur. However, the oxides of sulfur would be captured by the non-scaling alkalis, not by the calcium to any great extent. Furthermore, a sufficient hold-up time would be built into the system to allow pre-existing calcium sulfate particles to convert to calcium carbonate.

A further advantage of alkali sulfate formation is that these salts are usually saleable products. In particular potassium sulfate is a valuable fertilizer; this potassium is the alkali contaminant at Dragon Products and at many other cement companies. This is truly a fortuitous circumstance since it means that this process can clean flue gas, recover a solid waste, and combine and concentrate the contaminants from each into a saleable product. This produces no new wastes.

These theories were first subjected to laboratory bench-scale testing. The results were quite encouraging and indicated that the project deserved further scrutiny.

As a result, Dr. Morrison built a pilot plant that used actual plant side streams. After six months of operation, this pilot facility further verified the merits of the Passamaquoddy Technology Recovery Scrubber™ project; it actually functioned better than the laboratory bench scale model. Offending SOx emissions (oxides of sulfur) in the test gas stream were reduced by more than 90%. Test slurry

was decontaminated of alkalis enabling its possible use as kiln feed. Potassium sulfate was crystallized from solution by drying in a laboratory oven.

The project was then ready for selection as part of the DOE Innovative Clean Coal Technology Program.

APPLICABILITY

This process holds several advantages for manufacturers of cement. The relative importance of the benefits will vary with the application.

The first advantage involves the flue gas scrubbing capabilities of the Recovery Scrubber. This will allow cement manufacturers to use lower cost and generally more available fuels. Such frugal fuel use will enhance their competitive positions while conserving resources and keeping the air clean. The fuel trading allowances in the new Clean Air Act will increase the desirability of the Recovery Scrubber by allowing cement plants that do enhanced scrubbing to sell these credits.

A second advantage to cement manufacturers is the recovery of CKD. This recovery is a yield improvement and represents a savings in disposal costs as well as quarrying costs. For those manufacturers that now recycle all or part of their CKD while producing a high alkali cement, the Recovery Scrubber opens the possibility for economical alkali reduction.

A third benefit is the production of valuable potassium based fertilizer. In most cases this will probably not be the overriding concern, but will supplement the overall economic attractiveness of operating a Recovery Scrubber.

The Recovery Scrubber is rather unique. No other system to date exists which can both economically scrub flue gas and recover CKD. Passamaquoddy Technology estimates that there will be 184 applications for the Recovery Scrubber at cement plants within the first 10 years following its demonstration. This includes 43 Canadian kilns located mainly along the St. Lawrence River.

DESIGN/CONSTRUCTION

BASIC CEMENT TECHNOLOGY

There are two basic cement making processes. The wet process is older and is not favored due to higher energy costs of production. Newer cement plants almost invariably use a dry process. Dry process kilns can be further divided into long kilns, preheater kilns and preheater/precalciner kilns. The Dragon Products Plant uses the wet process. The Passamaquoddy Technology Recovery Scrubber™ can be applied to either a wet or a dry process cement plant.

In the wet process, kiln feed materials, including limestone, silicates, iron oxide, and aluminum oxide are ground and mixed together in a water slurry. These slurries are quite thick (e.g. 70% solids) to reduce the water that must later be driven off at the expense of heat energy. In order to more effectively accomplish drying, the back or cool end of a wet process cement kiln has a chain section that lifts the slurry and spreads it out for more intimate contact with the hot gasses coming up through the kiln from the hot fired end, or front of the kiln. The dried feed then proceeds to progressively hotter sections of the kiln, first being calcined and eventually forming the nodules of clinker containing the active calcium silicates and other ingredients of cement. This clinker is then cooled and finely ground with calcium sulfate to form cement or mortar.

In the dry process, the feed materials are ground, mixed, and fed dry. Long, dry process kilns function in a manner substantially similar to wet process kilns, except that the raw materials are not mixed with water. In preheater kilns, the feed is furthermore preheated by intimate contact with exiting kiln flue gas using a series of cyclones. A dry process system may even proceed so far as to precalcine the feed entering the kiln, hence the preheater/precalciner design. Dry systems therefore typically have shorter kilns.

Cement production necessitates extreme temperatures to accomplish the chemical transformations needed. The hottest part of a kiln may reach 3000°F. As a result, materials normally considered solids will volatilize. These include alkalis such as potassium and sodium and, in some cases, chloride compounds. Upon reaching the cooler back end of a kiln, the volatiles resolidify. Therefore the fine dust that gets entrained in kiln exit flue gas is not only kiln feed material and fine cement products; but it can also be high in undesirable alkalis and chlorides. At the Dragon Products site, this CKD is collected in a large bin. From there, it had been trucked to an on-site land disposal area; it is now conveyed to the scrubber.

The hot (approximately 500°F at Dragon Products), dust laden flue gas normally passes through a series of cyclones, electrostatic precipitators, or baghouses. Dragon Products uses cyclones followed by a baghouse. Due to heat losses and air inlet leaks, the gas for the Recovery Scrubber at Dragon Products typically arrives at the scrubber at 245°F to 300°F.

SCRUBBER DESIGN & CONSTRUCTION

The flue gas passing to the scrubber at Dragon Products is largely nitrogen, carbon dioxide, and water vapor, with some excess oxygen. Sulfur dioxide is typically one or two hundred parts per million. Oxides of nitrogen are also present at similar levels. The Recovery Scrubber was designed to handle 225,000 ACFM of gas at 245°F; however, typical daily operation runs somewhat below this level. The heat in this gas provides the energy needed to evaporate water in the crystallizer, leaving saleable potassium sulfate fertilizer.

The flue gas is quite manageable in carbon steel ducting until it cools below the dew point, at which time condensation forms. The wet flue gas then becomes very corrosive. This condition would then require expensive alloy construction if a non-direct contact heat exchanger were employed. Furthermore, the small amount of dust making its way through the baghouse would soon clog the heat transfer surfaces of such an exchanger. We therefore determined after some amount of deliberation and discussions with HPD that a direct contact heat exchanger made of fiberglass would be most economical and most effective in getting around these twin problems. However, the maximum operating temperature of the vinyl ester resin that was selected was 245°F. In order to ensure that the plant never exceed this criterion, a small pre-spray system of alloy material was installed to moderate and quench inlet gas as needed.

On the dust end of the flow sheet, the Recovery Scrubber is designed to handle 250 tons per day of CKD. This highly alkaline CKD contains about 3% potassium as K_2O , with the remainder being alkali and alkali earth oxides or, to a very low extent, sulfates (about 6% as SO_3), and inerts such as silicates and aluminum and iron oxides. The dry dust is conveyed by screw and by bucket elevator to a vortex mixer. The latter is a conical vessel that feeds directly into the Reaction Storage Tank. Reacted slurry enters tangentially and swirls over the walls preventing scaling from the fresh dust that is entering in the center top of the vortex mixer. The dust is thereby quickly quenched in a large volume of reacted slurry. This is done on a continuous basis, just as reacted material is continuously withdrawn from the bottom of the Reaction Storage Tank.

The gas to be treated and the potassium laden dust, in slurry form, meet in the Reaction Tank. This vessel may generally be described as a single sieve tray crossflow column. The flue gas arrives from the Recuperator cooled to 140°F and enters the bottom of the Reaction Tank. It then must pass through the sieve tray and percolate through the slurry of CKD flowing across the tray at 9,000 gallons per minute. This action creates a froth in which the gas is intimately mixed with the slurry, allowing absorption and reaction of CO₂ and SO₂ to form potassium sulfate and calcium carbonate in the Reaction Tank/Reaction Storage Tank system. The Reaction Storage Tank allows approximately seven hours of hold-up time to allow sufficient time for the carbon dioxide to react with calcium sulfate that may be present. The treated flue gas then passes through a mesh pad and out the stack free of about 92% of its initial SO₂ and of some of its oxides of nitrogen. Stack monitoring has shown that the average particulate emission from the scrubber is only 6.02 pounds per hour.

The reacted dust slurry leaves the Reaction Storage Tank and enters a set of settling tanks. Here the dust is allowed to separate from the liquid. The liquid, or leachate, is decanted off to the Crystallizer. The thick solids fraction at the bottom of the first Settling Tank is mixed with water and allowed to resettle in a second settling tank. This reduces the potassium sulfate in the interstitial water of the slurry returned to the cement plant.

The leachate from the settling system contains the potassium sulfate that should be crystallized and pelletized prior to sale. Because the leachate contains some small amount of suspended solids, it must first pass through a small sandbed filter. The leachate is then stored in the fiberglass Centrate Tank which acts as a surge feed tank to the Crystallizer.

The Crystallizer is by HPD, Inc. and is of a forced circulation design. The basic components include a vapor body, a shell and tube heat exchanger, and a 14,000 gallon per minute axial flow pump recirculating liquor between the two. The Recuperator previously mentioned supplies the heat used by the shell and tube heat exchanger. It does this by sending the fluid heated to about 130°F by direct contact with hot flue gas in the Recuperator to a flash tank held under 27 inch Hg vacuum by a vacuum pump through a connection via the shell and tube heater. The result is a flow of low pressure steam to the shell side of the heat exchanger. This vacuum pump is protected against any errant condensables load by use of a small shell and tube pre-condenser. Since this arrangement does not allow the temperature of the Crystallizer liquor to reach the atmospheric boiling point, the vapor body must also be held under 28 inch Hg vacuum by a

second vacuum pump in order to boil off water at its operating temperature of about 110°F. Water vapor from the vapor body is condensed in a shell and tube condenser and collected for reuse on the scrubber site.

As equilibrium is established in the Crystallizer, the liquor becomes a slurry of potassium sulfate crystals out of solution. These solids are then separated from the mother liquor by passage of a side stream from the vapor body through a centrifuge. The cake exiting the centrifuge must be below 10% moisture for proper pelletization, according to the pelletizer manufacturer.

The pelletizing system consists of a pin mixer followed by a vibrating bed dryer. In the pin mixer, water is added so that the material will coalesce properly. Upon leaving the pin mixer, moisture therefore typically runs about 15%. In order to develop maximum strength, the pellets need to be dried to about 2% moisture in the dryer. From the dryer, the pellets are stored in a silo capable of holding approximately one and one half months of potassium sulfate production.

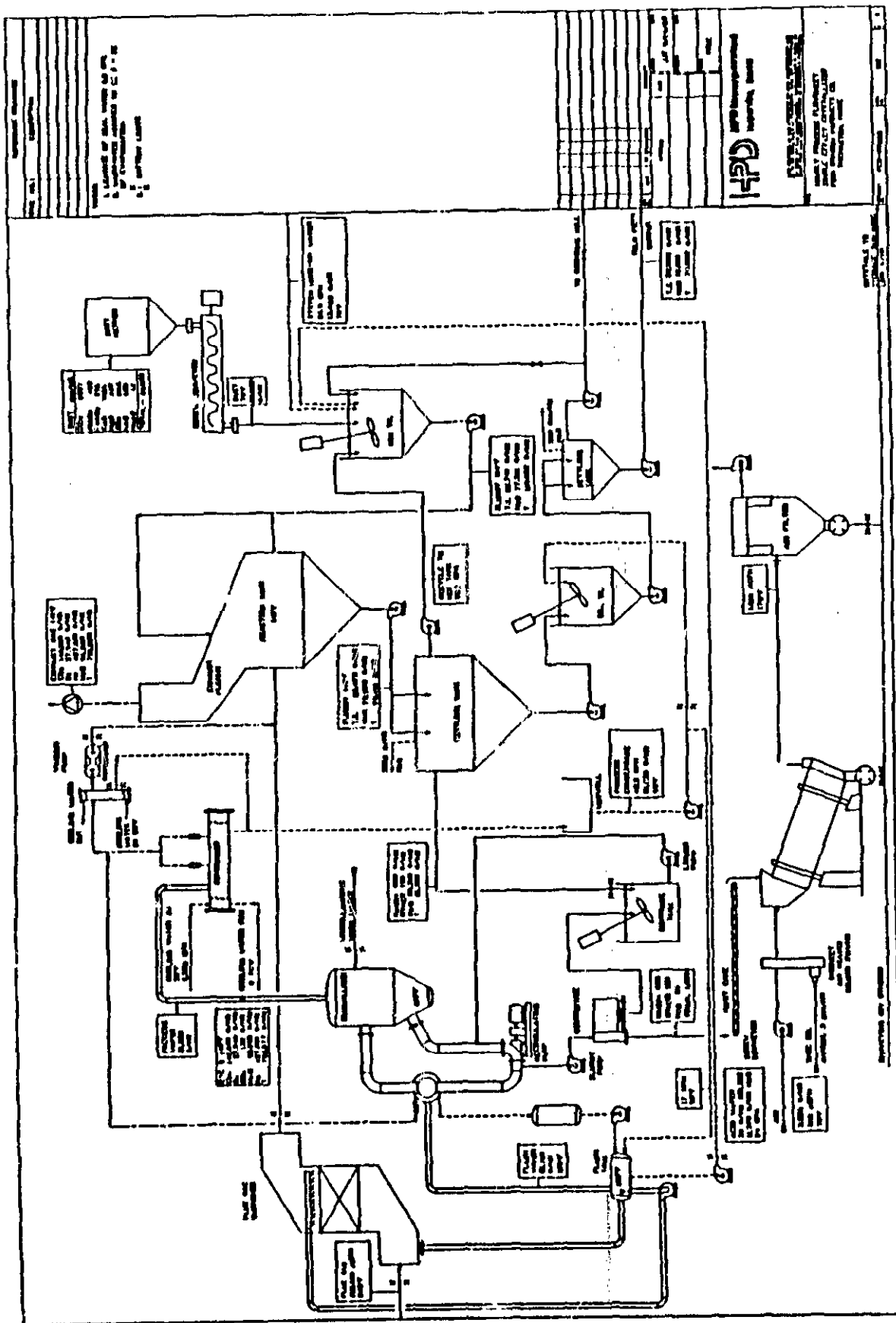
Since flue gas contains acidic gaseous components, water or condensate in contact with it becomes very corrosive. Therefore while we could handle the hot flue gas with a carbon steel fan and ducting, we had to find alternative economical materials of construction once the gas reached its dew point. Our solution was to use fiberglass for the Recuperator, exit ducting, and new stack, and a vinyl ester lining for the Reaction Tank and the Reaction Storage Tank. Gas handling parts that had to be of metallic construction, such as the pre-quench section before the Recuperator and the tray of the Reaction Tank were constructed of higher alloyed materials. The former was constructed of a combination of 904L, Inconel 625, and Hastelloy C22; the latter was constructed of 316L austenitic stainless steel. The Flash Tank, which handles water that has been in direct contact with the flue gas, is also built of fiberglass.

The vapor body is of carbon steel with a vinyl ester lining. This was done to prevent damage from the hot concentrated salt liquor. Some of the major recirculation piping was done in high density polyethylene for erosion corrosion resistance.

The shell and tube heater had to meet all the material requirements of both the vapor body and of the very corrosive flue gas heated fluid, while providing good heat transfer. An alloy known as 1925 hMo was eventually selected for shell, tubes, and tubesheets. This alloy has significant pitting resistance and should also resist the hot acidic Recuperator fluid.

Tanks and piping for the settling and wash system were constructed of bare carbon steel since it was felt that this material would provide a reasonable service life.

A flow sheet showing the interconnection of these components follows for ease of reference. Please note that there are discrepancies between the description above and the flowsheet. This is because the latter is based on early design concepts (e.g. the bottom of the Reaction Tank serving as the Reaction Storage Tank) while the description is based on actual construction as it evolved. Further information on this evolution follows.



FLOW SHEET
Figure 1

OPERATIONS

Shakedown of the Recovery Scrubber began on December 27, 1990. By that time, variable frequency drives had been tested, pumps had been "bumped", and other preliminary checkout had been accomplished. Simulation work was done on the Distributed Control System to help ensure only minor debugging at start-up. Piping was flushed to remove inadvertent construction debris and generally hydrotested for leak integrity.

HPD was on site on or about November 12 to check out the Crystallizer subsystem. This portion of the Recovery Scrubber was given a P&ID checkout, a hydrotest, vacuum test, and a water run to check for air leaks that might overload the vacuum systems. Work was done according to HPD's recommendations in their "Start-up and Commissioning Plan". As a result of start-up testing, a restricting orifice was placed in the Flash Tank inlet line to prevent an upstream control valve from cavitating. Some flange leaks were found and corrected. Crystallizer instruments were tuned or problems otherwise corrected.

A problem that did not become apparent until the actual shake-down run, was the unsuitability of the shell material of Crystallizer Heat Exchanger. Because the Recovery Scrubber is the first plant of its kind and no definitive corrosion data existed, the material originally chosen was carbon steel with a healthy corrosion allowance to compensate for the undetermined corrosiveness of the vapors coming over from the Flash Tank. However, acid components, either as gas or as mist, were pulled over in great quantity. They accumulated in the shell, forming an acid that quickly thinned or corroded through a sizeable area of that shell. We therefore removed the heat exchanger during the following shut-down and had the shell redone in 925 hMo. This is the same material as the tubes and tubesheets, which had held up very well in this environment. Furthermore, field corrosion coupons installed before start-up had by then indicated that this material would be a good choice.

The Reaction Tank was also pre-tested with water and flue gas to catch visible, gross problems with the construction and orientation of the tray. In this procedure, people in protective gear stood on top of the tray to observe the percolation of the fluid. The fuzziness of the top of the froth layer made accurate observation of differences in depth difficult, and no observations of the underneath side were made; however, these preliminary observations encouraged all who participated that the tray was generally sound and

that adjustments could be made to compensate for any irregularities. Such irregularities were found after start-up.

The sieve tray must be flat and not overly sloped. Standard tray flatness is normally about 1/8 inch. Because operating observation suggested a need to survey, we subsequently found that areas of the tray between structural supports sagged and that other areas also needed adjustment to bring them into specification. The indicators on the jackposts used to level the tray from outside the vessel were also found to be unreliable except for coarse adjustment.

In order to resolve these problems, we first had the construction contractor install additional bracing to correct sags between structural supports and adjust tray flatness where otherwise outside the 1/8 inch tolerance. This took several iterations. Tray slope was also adjusted and set by survey. We have found that alterations of tray slope to compensate for changes in operating parameters are not necessary, so that the tray can be left as adjusted by survey.

We also found shortly after start-up that the Reaction Tank would function better with less open area of holes. This is due to the fact that a certain amount of backpressure under the tray is required to keep the fluid on top from falling through. In order to operate throughout the normal range of flue gas that the cement plant emits, we found it expedient to seal off areas of the tray. It must be noted, however, that we seek to keep the undertray backpressure as low as possible because excess pressure drop through the tray translates into excess forced draft fan power consumption. Because of a recent consultation with a technical expert in fluidized bed design, we believe that it may be useful to further restrict the tray.

An additional Reaction Tank problem that now appears to be resolved involved the distribution of flue gas beneath the tray. Due to a transfer of responsibilities for Reaction Tank design, certain vessel attributes were changed or left out of the final design. Furthermore, due to a lack of experience with the design of these vessels, such discrepancies were not caught. As a result, about 80% of the flue gas entering the Reaction Tank flowed along the bottom 2 ft. of the 6 ft. high entrance. Then, because the beginning of the perforated sieve tray had been moved closer to the opening, the gas tended to travel to the far end of the tray, starving the near end and allowing leakage at the near end, and especially at the near end corners. Following consultations with a gas flow expert, a series of baffles and turning vanes were designed and retrofitted into the Reaction Tank. This has significantly improved the gas distribution.

Pluggage of the underneath of the Reaction Tank by material carried in with the gas or leaking through the tray has been a problem. After a few day's use, at best, pressure beneath the tray builds to the point that the vessel must be taken out of operation and the underside of the tray must be scraped clean. The above actions have helped, but were not adequate in themselves. We have had some success with sprays to capture particulate and to dissolve/wash particulate from the underside of the tray. Present plans call for the installation of a high pressure spray system that can clean the tray without shutting down. While there may be other more exotic and perhaps cheaper solutions, we feel that this solution will handle even unforeseen contingencies and will greatly enhance scrubber reliability.

Upon shakedown start-up, we discovered that the two large axial flow pumps had been shipped with the wrong motors. This fact had not been detected by Cianbro, which acted as the purchasing agent and had installed the pumps. As a result, the variable frequency drives could not operate within their intended ranges. The correct motors have since been obtained and installed.

A more immediate problem with these same pumps soon surfaced. The seals rapidly deteriorated due to upsets in seal water flow. This was finally resolved by supplying a surge tank with a separate seal water pump and a back-up interlock system to prevent seal damage in case of seal water failure. Several other pumps have since been put on this loop. The system has been quite successful in preventing seal failures.

A few days after the seal problem was resolved and the scrubber was restarted, another mechanical problem developed. That problem came in the form of a failure of the forced draft fan bearings and motor bearings. This 700 hp motor was 1954 vintage equipment with greased friction bearings. No vibration or temperature monitors had been installed. The fan manufacturer was contracted by Cianbro to evaluate the problem; however, his findings were somewhat inconclusive. A newer motor was purchased with oiled frictionless bearings. Monitors were installed and no subsequent problems have been experienced.

The shakedown also indicated that we needed to take further action to prevent or accommodate kiln upsets. The automatic control system on the forced draft fan was very successful in maintaining kiln operating pressure. Kiln operators commented on the smoothness with which changes from old stack operation to scrubber operation occurred. However, we found that if the automatic system was placed in manual control, human error could back-pressure the kiln, causing a

dangerous flashback condition. Furthermore, we discovered that we could extend the operating range of the scrubber at low gas flow, as occurs during kiln slow downs, if outside air could be introduced. Therefore Cianbro was directed to install blow-out panels for overpressure protection and an air intake damper to allow about 20,000 ACFM of outside air to be introduced. This was done before the scrubber was restarted in the Spring of 1991.

The method of feeding dust to the Recovery Scrubber was modified after some operating experience had been gained. Originally, dry dust was mixed with water from various sources in a separate agitated Mix Tank. The slurry was then pumped some distance to the reaction system where it was quickly neutralized by mixing with a large amount of reacted slurry. However, the line from the Mix Tank to the injection point, and to a lesser extent, the Mix Tank itself were found to plug. This was the result of gypsum scale formation and of the pozzolonic properties of the CKD. Our attempts to control the water streams and thereby the amount of sulfate added to the Mix Tank and our attempts to wear down the scale by increasing flow velocity were not entirely successful. The solution to our problem was to convey the dry dust all the way to the reaction system and to drop it directly into the center of a Vortex Mixer emptying into the top of the Reaction Storage Tank. This Vortex Mixer is a conical device into which reacted slurry is introduced tangentially. As a result, the walls of the Vortex Mixer are constantly washed and swept by non-scaling reacted slurry. This causes the fresh CKD to be introduced into the bulk of the slurry where it is neutralized without its clinging to the walls of any vessel. This technique has been very successful; no gypsum scaling plugs have since occurred.

While the Crystallizer subsystem has worked quite well, we have not to date formed the recovered potassium sulfate crystals into pellets of potassium sulfate fertilizer. Frequent outages during the start-up period due to mechanical problems, Reaction Tank tray pluggage, and short run times due to cement plant shut downs caused dilute potassium sulfate leachate to be pumped to the Crystallizer system. This leachate is always saturated in calcium sulfate and calcium carbonate, two sparingly soluble salts. The calcium sulfate will form some syngenite when combined with the potassium sulfate. The crystalline size and frailty of these contaminants then results in high fines in the slurry pumped to the centrifuge. As a result, the centrifuge does not get the moisture content of the salt cake down to the minimum 10% needed to pelletize in the pin mixer. If the potassium sulfate content of the leachate were at the 4% specified in the design, the contaminants should have an insignificant impact on pelletizer operation. Another option would be to add an additional drying step before the pin mixer. However,

since we need to increase the ratio of potassium sulfate to contaminant for product quality reasons, drying of the pelletizer feed has not been pursued. Since pelletization is a common procedure, we are confident of our capability to do so. Improved tray performance is expected to positively impact pelletization.

In a similar vein, a relatively inexpensive sand-bed filter system was added after start-up to help clean up leachate fed to the Crystallizer. This was done to remove fines (e.g. silicate platelets) that do not readily settle out in the settling tank system. This continuous filter system also acts to keep Crystallizer feed clean in the eventuality of a settling system upset.

Cooling water to operate the condensers of the Recovery Scrubber is supplied by a quarry pond derived from run-off water. Heated condenser water was then returned to the pond via a natural waterfall, thereby cooling it. After start-up, the summertime operating temperature of this water was found to be warmer than the 55° F anticipated. In order to increase cooling efficiency, a pipe header with a series of nozzles were installed on the cliff. These nozzles provide finer droplets than obtained with the natural waterfall; this results in greater evaporation. This modification seems to have sufficiently compensated for summertime heating of the water to allow effective Crystallizer operation. However, additional steps may need to be taken to improve cooling of the vacuum pump seal liquid.

Stack testing was conducted the week of December 16, 1991. Only preliminary results are available at this time. These results indicate a particulate emission from the scrubber stack of 6.02 pounds per hour, which, with the 22.91 pounds per hour from the clinker cooler stack is well below the cement plant combined permit level of 37.7 pounds per hour. The Recovery Scrubber stack flow meter readings were found to be on average 16% below actual flows. This is slowing issuance of the final report since the testing company needs to take into account the actual error at the time of gas pollutant measurement when estimating the pounds per hour of gaseous emissions.

UPCOMING ACTIVITIES

The Recovery Scrubber can only operate while the Dragon Products cement plant is operating. Because of low product demand and high inventory, the cement plant was shut down in mid-January, along with the scrubber. Plant forces will carry out maintenance activities during this outage. Cement production is not expected to resume until early May, at which time the scrubber will also be reactivated.

During this downtime, the hydraulic wash system previously mentioned will be installed beneath the tray in the Reaction Tank. This will involve modification of the tray structural support to allow for wash system travel. The tray may also require adjustment to assure that it is flat, properly sloped, and leak tight following these activities. This wash system is expected to greatly improve overall scrubber reliability and operability.

We also plan to install an additional mist eliminator pad to minimize carry-over from the Recouperator to the Reaction Tank. This device would be located in the Transition Piece at the entrance to the Reaction Tank and would not only capture particulate, but it would also improve control of the water balance in the reaction system by minimizing carry-over water introduced to the reaction system.

Additional scrubber activities will be undertaken in the down period as time permits. This will include inspection of corrosion coupons and rewiring to simplify and clarify the control scheme.

A report at a later date will detail the results of this work as well as the results of the stack testing.

CONCLUSIONS

The Recovery Scrubber has been designed and built and is in operation at Dragon Products in Thomaston, Maine. To date, flue gas has been scrubbed, waste CKD has been recovered and returned to the plant for cement production, and potassium sulfate fertilizer has been crystallized but not pelletized.

An accurate assessment of the amount of scrubbing of the flue gas is not available at this time. Typically, figures of approximately 92% removal of SO_2 and 5% to 15% removal of NO_x are indicated by on-line instrumentation. Stack monitoring has been conducted to verify accuracy of these instruments; but the testing report has not yet been received. However, preliminary information regarding particulate emission from the scrubber indicates very low numbers of about 6 pounds per hour.

The problems encountered have been largely mechanical and are typical of any chemical processing facility. These have been effectively and safely resolved.

The Reaction Tank still presents some operability problems in the form of tray pluggage, which requires downtime for cleaning. However, we feel that we have a solution to this problem well in hand. Expert consultation has indicated that there are actions that we can take to reduce, and even eliminate, this problem. Additionally, an on-line hydraulic tray wash system is planned that will maintain a clean tray regardless of the source of pluggage, whether it be regularly occurring or due to process upset.

We consider pelletizing as a secondary problem since potassium sulfate and many other materials are routinely pelletized. We are seeking to produce pellets in the most economical fashion with as little capital investment as possible (e.g. no extra dryers). Improved Reaction Tank operability should in itself permit pelletization of a quality potassium sulfate product. We believe that exercising patience by first producing a more concentrated leachate will pay dividends in the form of a simpler, less expensive process.

This first full scale demonstration plant has been successful to date and has shown the way to considerably improve future versions as the process becomes commercialized. A full report will be issued once all testing is completed.

